The importance of local thermal non-equilibrium in the modeling of a fractured hot dry rock reservoir

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Rachel Gelet[1], Benjamin Loret[2]

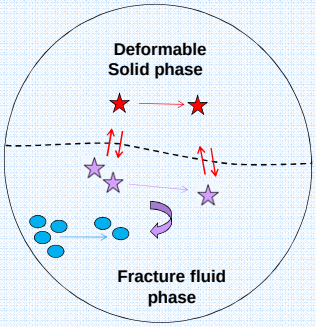
(1) Laboratoire GeM, Université de Nantes, ECN, CNRS, BP 92101, 44321 Nantes Cedex 3, France
(2) Laboratoire Sols, Solides, Structures – Risques, Université de Grenoble, B.P. 53X, 38041 Grenoble Cedex, France

rachel.gelet@univ-nantes.fr

Abstract Thermal recovery from a HDR reservoir, viewed as a deformable fractured medium, is investigated with a focus on the assumption of local thermal non-equilibrium. The numerical model is used to investigate the coupled thermo-hydro-mechanical behavior of the Fenton Hill site. The time profile of the outlet fluid temperature displays a double-step pattern, a feature which is interpreted as characteristic of established local thermal non-equilibrium.

The constitutive model uses a two-phase mixture and accounts for:

- ✓ Generalized diffusion
  - Hydraulic (Darcy)
  - Thermal (Fourier)
- ✓ Thermal convection
- ✓ Heat transfer



The significant contribution is the local thermal non-equilibrium ☆ ≠ ★

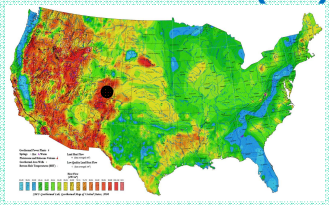
Characteristic times

$$t_{\text{Fourier,frac.}} < t_{\text{Fourier,solid}} < t_{\text{Convection,frac.}} < t_{\text{Darcy,frac.}}$$

10 000 years < 1 500 years < [2 days – 7 years] < 1 hour

- Large difference in characteristic times between thermal diffusion in the solid phase and convection in the fluid phase
- ➢ Local thermal non-equilibrium is required to accurately represent the overall thermo-hydro-mechanical behavior
- ➢ The thermally induced effective stress will trigger thermal shrinkage across the body of the reservoir that may lead to permeability change and fluid loss

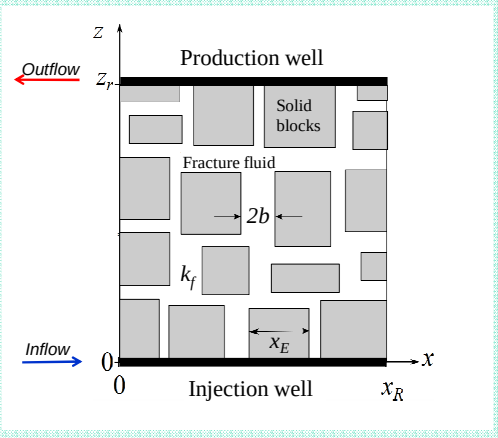
Site: Fenton Hill (US)



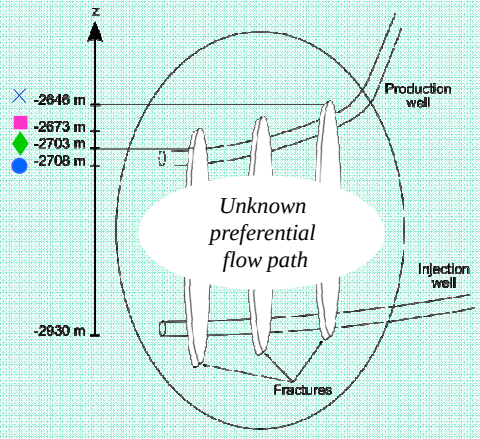
FE Simulation tools

- SUPG method
- Non-linear analysis treated with a Newton-Raphson algorithm
- Fortran language

Numerical setup

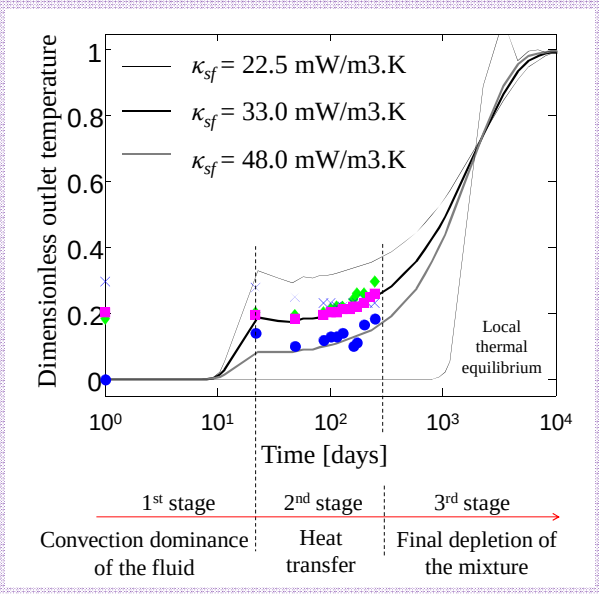


Compared with experimental data



THM coupled Results: relative temperature outlet versus time along the production well:

- Three parameters of the model are calibrated, namely the permeability $k_f = 8.0$ mD, the porosity $n_f = 0.005$ and the specific inter-phase heat transfer coefficient $\kappa_{sf} = 33.0$ mW/m^3.K
- Three stages characteristic of local thermal non-equilibrium are identified
- Local thermal non-equilibrium is characterized by a double step curve, while local thermal equilibrium is recognized by a single-step pattern



Summary

- Numerical results compare well with experimental ones
- The thermal drawdown curve is characterized by three stages, characteristic of local thermal non-equilibrium

Perspectives

Start experimental CHM and THM measures on real samples (ANR project in development)